

**BELLCOMM, INC.**  
1100 Seventeenth Street, N.W. Washington, D.C. 20036

**SUBJECT:** Preliminary Mars Excursion  
Module Shelter Design - Case 730

**DATE:** May 8, 1968

**FROM:** M. H. Skeer

ABSTRACT

A candidate approach to manned Mars surface exploration is deployment of separate manned descent/ascent vehicles and unmanned shelter vehicles, in lieu of a larger combined system. This scheme would incorporate surface rendezvous undertaken after simultaneous atmospheric entry and command maneuvers to minimize relative landing dispersion.

This memorandum considers the design of a two-man surface shelter compatible with the multi-vehicle entry mode. Sizing is predicated on two week surface staytime.

It is concluded that shelter weight (which includes a modest surface excursion vehicle) can be achieved for approximately 4,000 lbs. This is consistent with the estimated weight of a manned ascent vehicle so that identical entry systems (i.e., heat shield, landing gear, and retropropulsion) can be employed.

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MODULE SHELTER DESIGN (Bellcomm, Inc.) 22 p**

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MEMORANDUM FOR FILE

Introduction

A candidate approach to manned Mars surface exploration is deployment of separate manned descent/ascent vehicles and unmanned shelter vehicles in lieu of a larger combined landed system. This scheme incorporates surface rendezvous, achieved with simultaneous atmospheric entry and command maneuvers, to minimize relative separation dispersion.

This memorandum considers the design of a two man surface shelter compatible with the multi-vehicle entry mode. Sizing is predicated on a two-week staytime mission.

An assessment of Mars Shelter weight is undertaken which combines inputs from the Early Lunar Shelter study (Reference 1) and subsystem studies where a comparison was not justifiable due to differences in environmental constraints or mission requirements.

The preliminary portion of this memorandum describes a nominal Mars Excursion Module/Shelter mission and cites the general ground rules upon which weight allocations were based.

Mission Profile

The MEM arrives in the vicinity of Mars with an Orbiter module which establishes a planetary capture orbit. Two manned ascent/descent entry vehicles and the unmanned shelter separate from the parent ship and descend nearly simultaneously to the surface, either by direct entry (prior to the capture maneuver) or from orbit by aerodynamic braking and retro-propulsion.

The aerodynamic characteristics of the three vehicles are identical and all follow the same preprogrammed entry profile. The entry/landing mode does not necessarily minimize the size of the individual landing footprint but rather, minimizes relative landing dispersions, the crucial

element for surface rendezvous. A  $\Delta V$  contingency is allocated for approximately 1 minute hover and translation (in addition to retrobraking contingency) as further assurance against excessive landing separation. An alternate approach would be shelter craft entry in the Martian atmosphere several minutes ahead of the manned vehicles so that the latter could use aerodynamic forces to reduce dispersion during deceleration.

Should the shelter stage become inoperative, or separation distance be found excessive, the astronaut can return via the ascent vehicle after a curtailed staytime of 1 day, or less, with surface samples and limited data obtained at the landing site. Hence, the mission can be rated a partial success even without use of the shelter since abort is continuously available via a separate vehicle.

#### Shelter Design

The schematic representation of the Shelter design is shown in Figures 1 and 2.

The Shelter is packaged in a 20 foot cone or Apollo shape entry shell similar to the manned stages. The pressurized living quarters/laboratory is a cylinder with an ellipsoidal dome and flat (bulkhead) floor which is integrated with the descent stage structure. This achieves considerable volumetric packaging efficiency and enables internal subsystems to be mounted directly to the descent stage framework.

Platforms are provided adjacent to the pressurized cabin for mounting external equipments and experiments. The platform also provides support for airlock and mobility systems. This area is protected from entry heating and surface exposure by an aerodynamic shroud which is retained for passive thermal protection during surface staytime.

The airlock is a tension shell designed to accommodate two men, as dictated by safety requirements. The airlock exits at floor level and normal entrance and egress is via a platform hoist which is designed to provide assistance in returning an immobile astronaut to the shelter. The hoist is also used for unloading operational surface gear and equipment.

Surface mobility is provided by either a Local Scientific Survey Module (LSSM) (Figure 3) or a Flying Vehicle (FV) (Figure 4) discussed in detail in References 2 and 3. The FV mode is weight competitive only if the main landing vehicle retropropulsion residuals are tapped to provide range capability (in addition to the initial nominal range allocation).

Sizing Criteria

The Lunar shelter was designed to fit the Lunar Module/Truck (LM/T) weight/volume envelope, which is a relatively liberal allowance compared to the minimum design requirements of the MEM shelter. Consequently, in the current analysis, many of the LM/T contingencies and conservatisms (particularly experiments and mobility systems) are reduced or eliminated (Table 1). The LM/T crew size is reduced from 3 to 2, and staytime is reduced from 50 days to 14 days.

Other major factors contributing to differences in the two designs are:

- a) Meteoroid Protection - The meteoroid criteria governing the design of the Lunar shelter results in skin thickness of approximately 50% over the nominal required structural purposes. The Mars shelter by comparison requires no protection in excess of the cabin structure since the atmosphere completely attenuates high flux density micrometeoroids (Reference 4).
- b) Radiation Protection - No protection in excess of cabin structure and equipment is required for the Mars shelter. (The Mars surface dose rate is approximately two orders of magnitude less than that of the lunar surface.) (Reference 5).
- c) Storage and Activation - The Lunar shelter ground rules dictate a six month semi-dormant storage period prior to activation. Activation of the Mars shelter occurs immediately after touchdown so that no surface storage requirement in excess of the nominal staytime plus contingency is required.

MEM Shelter Weight Summary

The Mars shelter summary is given in Table 2. Total shelter weight is estimated at 4,060 lbs including 1,460 lbs of scientific equipment.

The experiments and subsystem weights are derived by prorating Lunar shelter weights given in Reference 1. Experiments, structures, power, and mobility systems are substantially modified, and are formulated separately in Appendices I - IV, respectively. Expendables are prorated on a man-day basis. ECS/LS and astrionics subsystems are essentially unchanged from the Lunar shelter design.

Discussion and Conclusions

The preliminary MEM shelter design and scaling exercise demonstrates the feasibility of performing reasonable Mars surface exploration program within a relatively modest surface shelter payload allotment of 4,000 lbs for 2 men-2 weeks staytime. Compromises made by comparison to the Lunar shelter mission are believed warranted because of the marked increase in transportation costs for Mars exploration. However, the basic weight reductions arise from reduced crew, staytime, environmental and mission requirements.

For planning purposes, the selected MEM shelter is intended to be a representative design point compatible with a minimum mission capability. Combined with the results of the Lunar shelter study, which represents an upper bound, a rational basis for scaling the spectrum of intermediate mission requirements is provided.



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1013-MHS-sjh

Attachments  
References  
Figures 1-4  
Tables 1-2  
Appendices I-IV

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REFERENCES

1. Early Lunar Shelter Design and Comparison Study, Garrett/AiResearch Manufacturing Division, 67-1964-2, Contract Number NAS 8-20261, February, 1967.
2. Lunar Surface Mobility Systems Comparison and Evolution Study (MOBEV), The Bendix Corporation, BSR-1315, Contract Number NAS 8-20334, June, 1966.
3. A Study of Lunar Flying Vehicles, Bell Aerosystems Company, 7217-928001, Contract Number NAS 8-11387, June, 1965.
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TABLE 1

## COMPARISON OF MEM SHELTER AND LUNAR SHELTER MISSION CHARACTERISTICS

Mission Characteristics	Lunar Shelter	MEM Shelter
Staytime Days	50	14
Crew Size	3	2
Volume Constraint	LM Ascent Stage Volume Envelope	Minimum Volume
Weight Constraint	LM Ascent Stage Weight Envelope	Minimum Weight
Quiescent Surface Storage	6 months	None

TABLE 2

Item	Weight		% of L/S	Comments
	MEM Shelter	Lunar Shelter		
0.0	(4064)	(10 260)	(39)	
1.0	(3036)	( 7309 )	(41)	
1.1	1010	465	75	Volume of shelter reduced from 700 ft <sup>3</sup> to 575 ft <sup>3</sup> for 3 vs. 2 men respectively.
1.1.1	1345	850		Skin thickness is reduced from 030 to 020 consistent with reduced meteoroid constraints. Details in Appendix III.
1.1.2		---		
1.1.3		240		
1.1.4		---		
1.1.5		25	135	
1.1.6		220	25	
		60	240	
			95	
1.2			34	Tank weight prorated on man-day basis.
1.2.1	213	88	307	Control weight is not prorated.
1.2.2		76	173	
1.2.3		49	145	
1.3			45	Second fuel cell eliminated. Quiet- cent storage power unit eliminated. Details in Appendix IV.
1.3.1	334	746	385	Peak power for subsurface drill reduced.
1.3.2		186	120	
1.3.3		67	77	
1.3.4		---	164	
		81		
1.4	103	287	36	Radiator designed internally with thermal shroud (Item 1.1.2)
1.4.1		103	122	
1.4.2		---	165	

TABLE 2 (Continued)

Item	Weight		% of L/S	Comments
	MEM	Shelter		
1.5	EC/LSS Atmosphere Supply & Humidity Control & Ventilation Water Management Crew Provisions Waste Management Packaging Shelter Furnishings	666	821	81
		66	66	Crew provisions modified consistent with reduced crew size. Other systems assumed unchanged.
		148	148	
		70	70	
		231	347	
		15	15	
		47	67	
1.6	Astrionics Communications Command & Control Television Instrument/Telemetry	90	109	No change assumed.
		240	240	
		85	85	
		48	48	
		24	24	
		83	83	
		3240	45	
1.7	Scientific Equipment LSSM or FV Mobility Group Experiments Deep Drilling Local Sampling Emplaced Scientific Station Astronomy & Environmental Satellite ESS Units	1446	1389	Substantial reduction in science payload.
		367	687	Minimum roving vehicle selected.
		341	242	
		106	220	
		382		
		250	417	
		---	59	
2.0	Expendables Mass	---	226	
		(1053)	(2951)	(35)
2.1	Fluid Storage $LH_2$ $LO_2$ $GO_x$	420	1657	25
		36	152	Prorated on man-day basis.
		334	1380	
		50	125	

TABLE 2 (Continued)

Item	Weight		% of L/S	Comments
	MEN Shelter	Lunar Shelter		
2.2				No change assumed.
2.2.1				
2.2.2				
2.3				
2.3.1				
2.3.2				
2.3.3				
2.3.4				
2.3.5				
Thermal Control Water-Glycol	69	69	100	
Freon 21	26 43	26 43	56	
EC/LSS	564	1001		
Food	66	185		Food and personal hygiene prorated on man-day basis. Water via reclamation is presumed unchanged.
Personal Hygiene	25	79		
Water	137	137		
Water Management	6	10		PLSS cannisters reduced consistent with reduced ESA.
PLSS LiOH Cannisters	330	590		

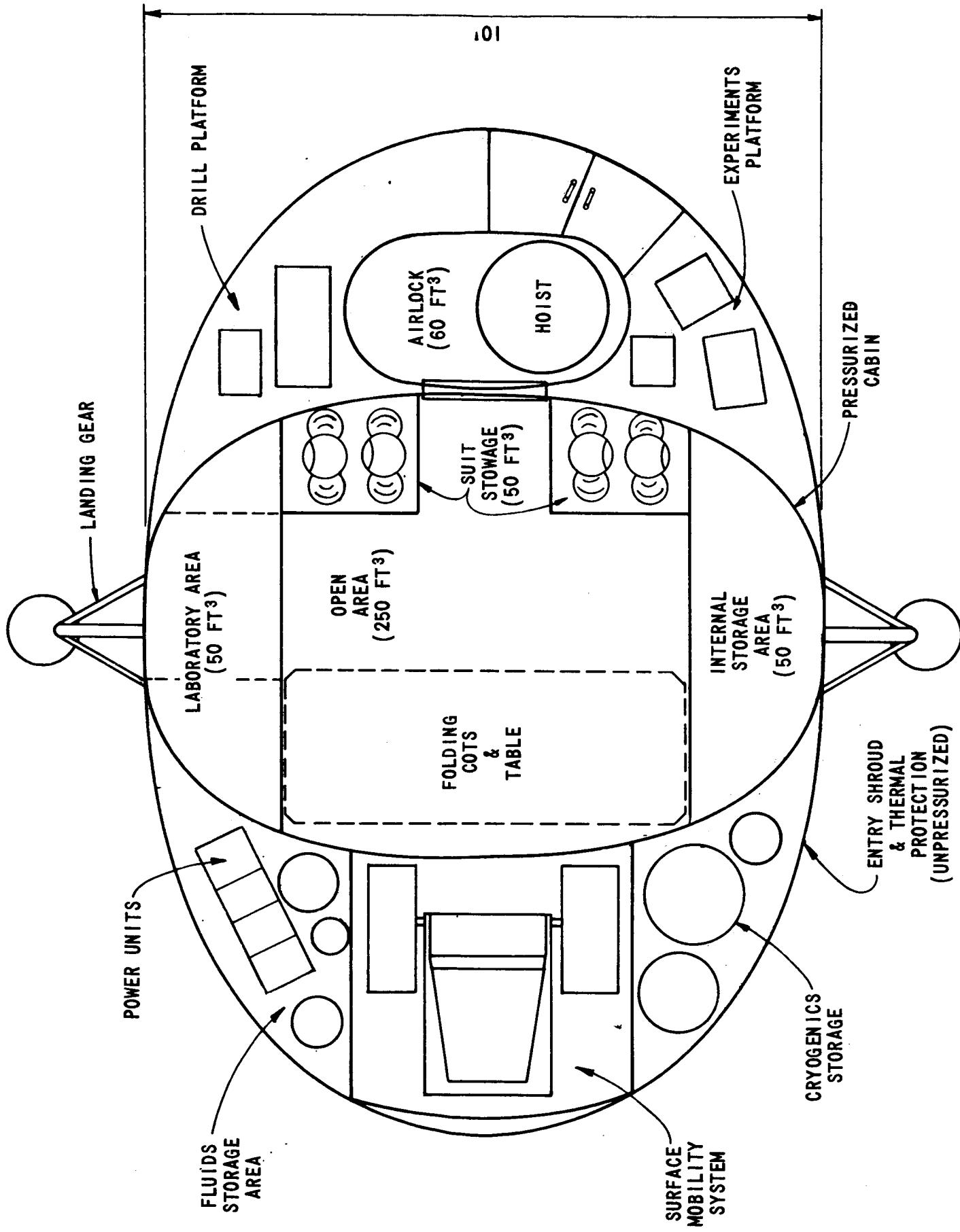


FIGURE I - MEM SURFACE SHELTER

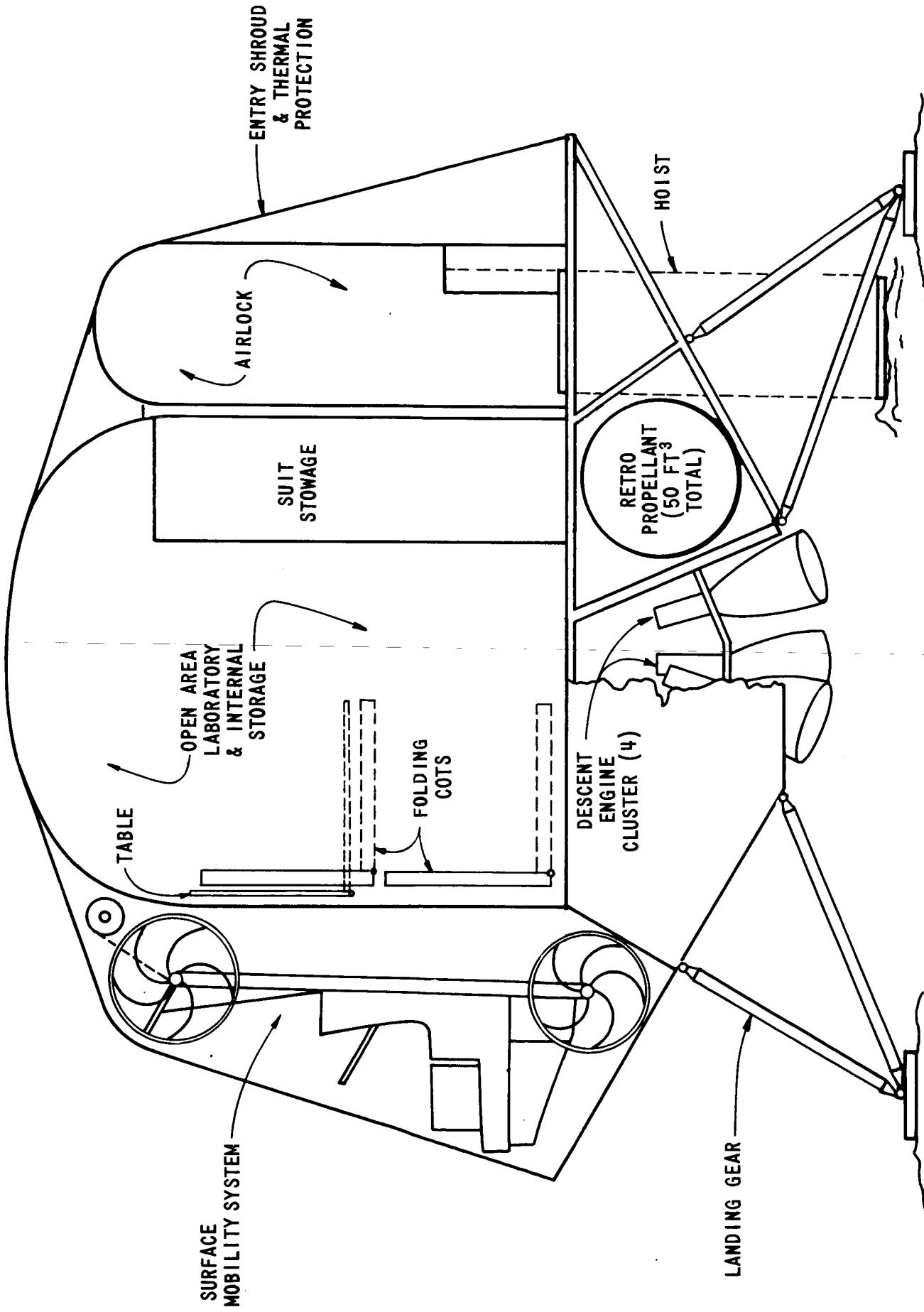
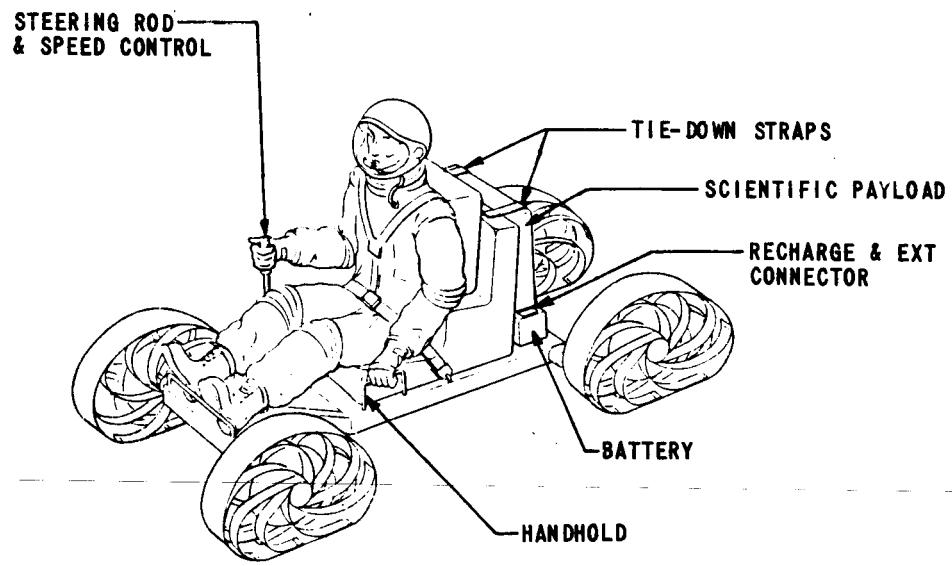


FIGURE 2 - MEM SURFACE SHELTER



CREW SIZE	1
MISSION DURATION	14 DAYS; 3 HRS/SORTIE
RANGE	15 KM/SORTIE; 420 KM TOTAL
SCIENTIFIC PAYLOAD	10 KG
GROSS MASS	135 KG

FIGURE 3 - LUNAR ROVING VEHICLE (REF. 2)

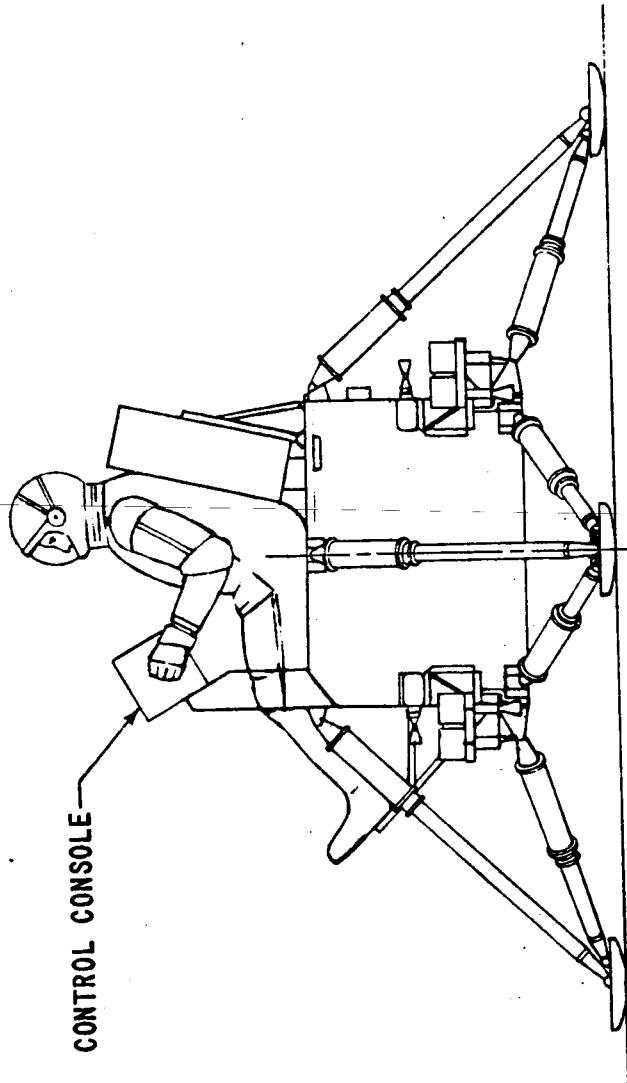


FIGURE 4 - FLYING VEHICLE (REF. 3)

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APPENDIX I

Science Payload

The science payload is grouped in two basic areas:  
1) Station, and 2) Mobility systems.

The Station group includes all experiments that may be accomplished within convenient walking distance of the shelter as well as the immediate shelter site. The principal experiments are a 30 meter drill, fields measurements, seismic studies, geology, and environmental monitoring. A long term scientific station is also to be emplaced at the station. (It is presumed the main scientific station and satellite stations will communicate with an unmanned orbiter.)

Excursion sorties are devoted to extensive photography and radiometry, collection of samples, and emplacement of satellite scientific stations. Payload per sortie is presumed to be 100 lbs maximum. The total mobility group weight is 242 lbs which includes three satellite stations.

The total scientific payload weight breakdown is given in Table A1. A comparison of Lunar shelter experiments is included to gage compromises made for achieving a reduction in landed payload.

TABLE A1

Comparison of MEM Shelter and Lunar Shelter Scientific Payloads

Item	Weight (Lbs)			Comments
	MEM Shelter	Lunar	Shelter	
<u>Mobility Group</u>				
LSSM	367	1380		
Scientific Equipment	341	520		
Multiband Photography and				
Radiometry	77			
Sample Containers and Hand Tools	24			
Satellite Emplaced Scientific				
Stations	140			
Surveying Tools	100			
<u>Station Group</u>				
Deep Drilling Equipment	107	250		
30/100 meter drill	85	200		
Drill Experiments	22	50		
Emplaced Scientific Station	250	417		
Local Sampling and Environmental				
Equipment	395	844		
Gravity Meter	11			
Nuclear Measurements to Package	29	11		
Seismic Deep Refraction Equip.	220	36		
Gas Analyzer	16	48		
Surface Electrical Package	18	5		
Telluric Currents Package	22	16		
Magnetometer	7	18		
Shelter Geology Equipment	50	27		
Penetrometer	7	7		
Radiometry Package	9	65		
Erosion Samples	3	7		
Environmental Exposure Panels	3	3		
				Substantially curtailed program.

TABLE A1 (continued)

Item	Weight (Lbs)	Comments
Astronomy Experiments	-	
3 Meter Drill	-	
Sonic Velocity Equipment	-	
Electrical Induction Package	-	
Meteoroid Ejecta Detectors	-	
Tissue Equivalent Ion Chamber	-	
Total	(1460)	(3411)
		{ Experiments eliminated.

**BELLCOMM, INC.**APPENDIX IIMobility System

Two candidate mobility systems are considered:

- 1) Local Scientific Survey Module (LSSM), and 2) Flying Vehicle (FV).

1) LSSM - As described in Reference 2 the baseline vehicle is a one man transport device provided to enhance the range and operating radius of an astronaut during exploration sorties.

The selected vehicle weighs 367 lbs and has a scientific payload capacity of 100 lbs. Mission power requirements are sized for 14 sorties (i.e., 1 per day) at 3 hours per sortie. The nominal sortie range is 5 miles and the total mission range is 140 miles. Batteries must be recharged between sorties.

The vehicle consists of a mobility structure subsystem, power subsystem and a crew station as shown in Figure 3. The LSSM weight breakdown is as follows:

SYSTEM	WEIGHT (lbs)	REMARKS
Mobility/Structure	220	Avg. Speed: 3.1 mph Locomotion: 4 flexible, individually powered wheels Steering : Manual
Power	82	Batteries: 1.5 kw-hr/ charge
Life Support	---	PLSS
Crew Station	32	Seat, Minimum Controls and Displays
Astrionics	---	Communications: Via PLSS Navigation : Visual Contact
Tiedown and Unloading	33	Manual, Hoist
Total	367	

2) FV - Use of any sort of propulsive vehicle is predicated on the assumption that contingency and residual propellants for descent retropropulsion will be available from at least one, or as many as three descent vehicles. Obviously retro contingencies cannot be counted on to ensure the "desired" amount of FV propellants, but it is reasonable, in view of the probabilistic aspects of a .99 contingency allocation, that a good portion of the contingency fuel will be available. Assuming 500 fps velocity contingency allocations per descent vehicle as much as 1,500 lbs of propellant will probably be usable for added FV range capability.

The FV described in References 2 and 3 is of open cockpit design for one man operation. No provision for life support or environmental control is provided other than hard suit and PLSS backpacks. Control is provided manually by thruster gimballing. Communication is limited to PLSS VHF, line of sight, voice systems. Navigation and guidance is done visually and with a strap down inertial guidance system or sextant to determine initial flight direction. A minimum system is conceived to consist of a simple pitch attitude sight, timer and radar altimeter with displays of altitude and altitude rate.

For purposes of comparison, a flying vehicle similar in weight to the LSSM is considered. Gross weight including initial propellant is 334 lbs plus 33 lbs for handling equipment. Usable propellant weight is 232 lbs. Employing Compound A/MMH earth storable propellants with specific impulse ( $I_{sp}$ ) equal to 330 seconds, total  $\Delta V$  for man, hard suit, and backpack, plus 100 lbs payload is 3,600 fps. Assuming a horizontal trajectory, with a 200 fps horizontal velocity, 3 nmi round trip range on a single stop sortie is obtained. 1,500 lbs of residual propellants (from the 3 vehicles) enables a total range of 21 nmi to be achieved on six one stop sorties. Although range does not compare favorably with the LSSM, travel time to any site is on the order of several minutes so site staytime for a fixed extrashelter time limit is extended considerably.

APPENDIX III

## STRUCTURES AND INSULATION

Item	Weight (lbs)		Comments
	MEM Shelter	Lunar Shelter	
Main Structure	465	850	
Pressure Skin & Lands Stringers and Longerons Frames	107 35 88	195 40 105	Skin, stringers and frames reduced consistent with reduced volume and meteor- oid requirements. Airlock reduced from 125 ft <sup>3</sup> to 75 ft <sup>3</sup> . Floor, supports, and leveling reduced ac- cording to reduced area and weights. Docking struc- ture eliminated. Viewing ports and periscope re- placed by vidicon.
Airlock Door and Mechanisms	55	95	
Door Penalty	25	35	
Floor and Supports	70	95	
Fittings	30	40	
Leveling	55	100	
Docking Structure & Hatch Viewing Parts & Periscope	--	85	
Entry and Thermal Shroud	240	60	
Meteoroid Provisions	--	--	
Bumper Panel(0.020 Fiberglass Sheet)	135	60	Meteoroid bumper eliminated.
Standoffs and Foam	--	80	External structural pro-
Thermal Insulation	--	55	visions and unloading equip-
External Structural Provisions	25	25	ment reduced in accordance
Equipment Unloading, Crew Access	120	240	with subsystems and ex-
TOTAL	(1010)	(1345)	periments weight.

APPENDIX IV

Comparison of MEM Shelter 14 Day Mission and Lunar Shelter  
14 and 50 Day Mission Electrical Power Budgets

Item	Energy (Kw-hr)			Comments
	MEM Shelter	Lunar Shelter 14 days	50 days	
EC/LSS	63	63	244	Prorated on staytime basis. Reduced crew systems power neglected.
Communications	24	24	86	Prorated on staytime basis.
Experiments	34	82	99	Reduced subsurface drill requirements and reduced experiments payload.
Instruments & Controls	33	33	120	Prorated on staytime basis.
Cryogenics	13	13	56	Prorated on staytime basis.
LSSM	30	88	395	Minimum LSSM assumed.
PLSS	16	16	65	Prorated on staytime basis.
TOTAL	213	319	1066	Second fuel cell and secondary power system eliminated.

## APPENDIX IV (Cont'd)

Comparison of MEM Shelter and Lunar Shelter (Optimized Configuration) Power Systems Weight

Item	MEM Shelter	Weight (lbs)		Comments
		MEM Shelter	Lunar Shelter	
<u>Primary Power System</u>				
Fuel Cells (2)	186	146	385	
Launch Umbilical		10	292	Two fuel cells @ 2 Kw/cell.
Protective Circuit (3)		6	10	One fuel cell adequate for MEM.
Meteoroid Protection		--	9	
Regulators (3)		24	38	Two circuits adequate.
			36	No meteoroid protection required.
			36	Two regulators adequate.
<u>Secondary Power System</u>				
Ag-Zn Battery	67	50	120	Used during short landing phases
ECA		12	90	of mission and to start up fuel
CSM Umbilical		5	20	cells. Energy decay penalty due
			10	to wet-activated standby eliminated
				for MEM shelter.
<u>Auxiliary Power System</u>				
RTG	--		77	Used during quiescent storage.
NI-Cd Battery (4)			45	Entire system eliminated for MEM
Protective Circuits (4)			24	shelter.
			8	
<u>Power Distribution System</u>				
Circuit Breakers (9)	81	10	214	5 circuit breakers adequate for MEM.
Battery Charger (2)		25		1 battery charger adequate for MEM.
Control & Instrumentation		18		Prorated on power systems weight
Cabling & Junction Boxes		18		basis.
Miscellaneous		14	80	Prorated on power systems weight
		14	27	basis.
TOTAL	(334)	(796)		Corresponds to basic requirements.

# BELLCOMM, INC.

Subject: Preliminary Mars Excursion  
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